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FINAL REPORT: PANDORA MOTH, MOUNTAIN PINE BEETLE, AND FOREST HEALTH IN THE ARAPAHO NATIONAL FOREST

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Final Report: Pandora Moth, Mountain Pine Beetle, and Forest Health in the Arapaho National Forest

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July 2007

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INTRODUCTION

The Arapaho National Forest has a history of pandora moth (*Coloradia pandora*) outbreaks and is currently experiencing the largest mountain pine beetle (*Dendroctonus ponderosa*) outbreak in the recorded history of Colorado. This work is the first attempt at documenting past pandora moth outbreaks in lodgepole pine (*Pinus contorta*) using dendrochronology and also examines the condition of the forest prior to mountain pine beetle infestation.

Pandora moth is a phytophagous insect that consumes leaves of conifer trees. This insect has host species of ponderosa pine (*Pinus ponderosa*), lodgepole pine, and Jeffrey pine (*Pinus jeffreyii*) (Patterson 1929; Wygant 1941; Carolin and Knopf 1968; Furniss and Carolin 1977). The insect's only eat the older needles and leave the buds and young needles so there is only a 2% mortality rate on these trees (Patterson 1929, Massey 1940). The loss of the biomass places a strain on the tree's growth, yielding smaller ring widths. Speer *et al.* (2001) found that the ring of initial decrease in growth was smaller and had thinner latewood and this pattern persisted for the length of the pandora moth signature which lasted from 4-12 years. This insect prefers loose soils made of granite and pumice. The moth has a two year life cycle during which the larvae burrow into the soil for the second winter, making the soil conditions one controlling factor for the distribution of the insect.

Few studies have been conducted on the pandora moth. Carolin and Knopf (1968) and the U.S. Forest Service have constructed maps on the distribution of the moth. An Indiana State University graduate student is currently working on an updated version of a distribution map using a geographic information system (GIS) that incorporates

multiple environmental factors such as climate, elevation, soil type, and vegetation (Tiemogo, unpublished PhD proposal). This habitat map will predict the likely occurrence of pandora moth and guide future sampling efforts that will help to refine the final map.

Speer *et al.* (2001) did the first dendrochronological study on the moth in Oregon and identified a distinct tree-ring signature. They found that the moth has been in the ecosystem for the length of their record (622 years), has duration of 8-19 years, and tends to spread from an initial point (Speer *et al.* 2001). Pohl *et al.* 2006 also studied pandora moth in Oregon by comparing and removing climate variables, and fire to ensure a positive pandora moth outbreak.

All current pandora moth tree-ring studies have been conducted in ponderosa pine. This work examines the effect of pandora moth on lodgepole pine in Colorado. As this is a new species system, we expect that the insect signal could be different from its signature in ponderosa pine (mentioned above). This work will document the effect of pandora moth on lodgepole pine and try to reconstruct previously undocumented outbreaks in the past. A series of study sites scattered spatially throughout its entire range will give us a better idea of the entire species dynamics and is a good natural laboratory to examine general insect outbreak dynamics.

METHODS

In 2004, an Indiana State University field geography techniques class along with a Forest service entomologist (Jose Negron) sampled 80 lodgepole pine trees in a portion of the Arapaho National Forest at King Mountain Ranch. The trees were selected from

four sites throughout the ranch. In summer 2006, six additional sites were selected from old growth forests throughout the Arapaho National Forest (Figure 1).

Older trees were selected from the forest by observing several old tree characteristics such as flat top, dead branches, heavy large branches, large diameter, and spiral grain (Fritts 1976). All trees were cored at breast height (1.5m) with a Haglof 5.15 mm increment borer. Two cores were taken from each tree parallel to contour in order to avoid reaction wood and to include all rings for the individual trees. The cores were stored in paper straws to allow them to air dry and for safe transport back to the lab where they were dried in a fume hood for two weeks and then mounted with Elmer's white glue on pre-fabricated core mounts. They were sanded with progressively finer grit paper (ANSI 120 grit (105-125 μm), ANSI 220 grit (53-74 μm), ANSI 320 grit (32.5-36.0 μm), and ANSI 400 grit (20.6-23.6 μm)) in order to analyze individual ring widths (Stokes and Smiley 1996; Orvis and Grissino-Mayer 2002). A subset of the cores were dated using skeleton plots (Stokes and Smiley 1996) to develop a master chronology and the remaining cores were dated using the memorization method (Douglas 1941). A Velmex measuring system using Measure J2X software was used to measure all ring widths to 0.001 mm precision. The dating and measuring accuracy was checked using the COFECHA program (Holmes 1983; Grissino-Mayer 2002).

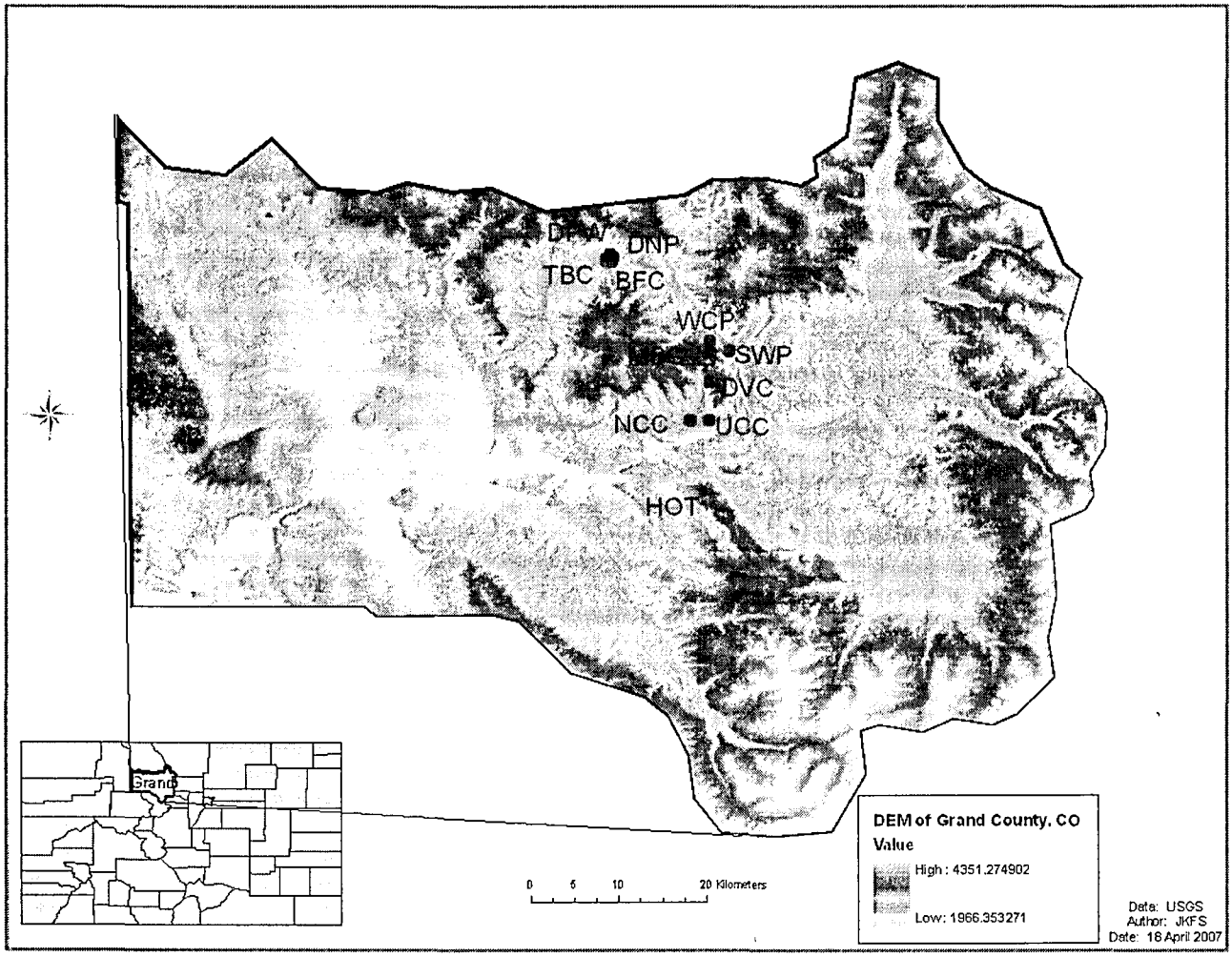

Figure 1: Host (dark blue) and non-host (light blue) chronologies collected at the Arapaho National Forest, Grand County, Colorado.

COFECHA

We analyzed all our sites separately. COFECHA was used to verify dates of our cores. Two statistics are reported using COFECHA, average mean sensitivity, and series intercorrelation. The average mean sensitivity indicates whether the ring widths vary enough to record climate parameters (*i.e.* precipitation). The higher the number, the more sensitive the cores are to climate. A sensitivity of 0.200 is an arbitrary goal for climate reconstruction. The series intercorrelation is how well the cores are correlated, demonstrating a stand-level signal.

ARSTAN

After our dates were verified, we used program ARSTAN (Cook 1985). ARSTAN allows dendrochronologists to display their data visually and standardize the series. ARSTAN takes the raw ring widths and averages them together for individual tree cores, trees, and the entire stand. We used ARSTAN to standardize our data to remove 'noise' in our data for the particular research question. For example, climatologists are interested in the climate signals in their data, but dendroecologists would remove the climate signal because it masks the full affect of the insect on the trees. Also, trees tend to grow much faster when younger than when they are older and this trend is displayed in our data as a negative exponential curve and needs to be removed. The results of these standardizations are three different chronologies: the standard chronology, the residual chronology, and the ARSTAN chronology. All of these chronologies are index values that have taken age-related growth trends into

consideration. The residual and ARSTAN chronologies have removed autocorrelation from the series which is introduced by the biological memory of previous growth.

With our standardized chronologies, we then looked at how various climate variables (Palmer Drought Severity Index (PDSI), temperature, and precipitation) correlate with our individual site chronologies. If our correlations are below our significance level, then we reject that they are significantly correlated (alpha = 0.01 unless otherwise stated).

Mountain Pine Beetle Analysis

We further separated our data to analyze forest health conditions before the recent mountain pine beetle outbreak. Many of our tree cores had blue stain fungus indicating that the trees were ~~heavily damaged~~ by mountain pine beetle. We also have a subset of our cores that were killed by mountain pine beetle. We plotted the standardized chronologies of the cores with blue stain fungus versus no stain separated for each site.

Identification of Pandora Moth Outbreaks

We examined the wood visually and used the computer program OUTBREAK to identify pandora moth outbreaks. OUTBREAK takes the individual ring widths for each tree-level chronology and compares them to a non-host chronology from another tree genus that is not affected by pandora moth. Based on ring width criteria that need to be calibrated for each new species and site, OUTBREAK calculates when pandora moth outbreaks have occurred in the past. Only two studies have conducted dendroentomological analysis on tree cores from pandora moth outbreak areas (Speer *et*

al. 2001; Pohl *et al.* 2006). We first used the criteria set forth by Speer *et al.* (2001). Our sites are from different states (Oregon versus Colorado) and on different species of wood (ponderosa pine versus lodgepole pine) so we anticipated that we would have to develop our own criteria for this new species and environment. We have historical documentation of a pandora moth outbreak in the 1930s in this area (Massey 1940). We used this outbreak to determine the effect of pandora moth on lodgepole pine and used that signature to calibrate OUTBREAK to this new site.

For those sites that were significantly correlated with our climate variables, we used a non-host (control) chronology to remove the climate signals and to ensure that only pandora moth signals were analyzed. The control chronology was selected from the International Tree-Ring Databank (ITRDB). We selected a non-host tree species (*Pseudotsuga menziesii,* Douglas-Fir) to ensure that the species did not respond to pandora outbreaks from a location near our study sites (Hot Springs, CO, authors: C. Woodhouse, M. Losleben, and J. Lukas).

RESULTS

All chronologies have strong series intercorrelations, but the mean sensitivities demonstrate that these are relatively complacent sites (Table 1). These values are normal for lodgepole pine throughout its range. Five out of ten sites responded to one or more climate variables (Table 2). The most frequently significant variable was PDSI or specifically July PDSI indicating that soil moisture in July is a limiting factor for tree growth for Arapaho lodgepole pines. Graphs for all sites are included in appendix A.

Table 1: Chronology statistics for all sites.

Site	Series Intercorrelation	Avg. Mean Sensitivity	Total Dated Rings	Age Range	Aspect
DNP	0.494	0.147	4061	1874-2003	N
DPW	0.432	0.151	4884	1863-2003	NE
BFC	0.535	0.166	6264	1732-2003	NE
TBC	0.481	0.136	4296	1867-2003	W
DVC	0.457	0.176	9420	1702-2005	SW
MSC	0.410	0.162	5618	1661-2005	N
NCC	0.516	0.156	4793	1862-2005	SSW
SWP	0.434	0.162	4474	1746-2005	SW
UCC	0.437	0.163	10413	1653-2005	SE
WCP	0.488	0.144	5150	1865-2005	NE

Table 2: Significant climate variables. Numbers in parentheses are pearson's r correlations and the variables and numbers in red are the most significant for that site. Also included is the non-host site to indicate that it was sufficient to remove the climate signals from our host sites.

HOST NCC	HOST DNP	HOST BFC	HOST WCP	HOST DVC	NON-HOST HOT
July D (0.338)	July & Aug Dp Jan D June-Aug D July D (0.393)	July Dp, Jan D-Aug D July D (0.445) Summer D	All PDSI Oct Dp-Dec D July D (0.420)	May-Aug D Oct D Summer D July D (0.395)	All PDSI Dec Dp-Dec D June D (0.517)
	July Pp (0.369) July P		Annual Precipitation (0.323)	June Temp (-0.355)	Annual Precipitation (0.340)
					Summer Temperature (-0.378)

The simple comparison of trees with the blue stain fungus present versus those without the blue stain shows no difference among all sites (Figure 2-See Appendix B for all graphs). This indicates that the trees being more heavily affected by mountain pine beetle are not more stressed than trees not currently affected by the outbreak. All of the trees in this analysis are from within the same stand. The lack of blue stain on the cores may not be an accurate indicator of mountain pine beetle damage in all trees. One site had no blue stain present and another site had blue stained on every core so both sites were excluded from this comparison. None of the sites shows a decrease in growth prior to mountain pine beetle arriving on the site, suggesting that this outbreak was not initiated because of a decline if forest health.

Most sites had at least one pandora moth outbreak while several sites had multiple outbreaks throughout the stands history. Potential outbreaks that we found occurred in 1683, 1719, 1757, 1833, 1865, 1882, 1894, 1914, 1928, 1939, 1956, 1965, 1985, and 2000 (Figure 3-See Appendix C for all graphs). Our sample depth prior to A.D. 1800 is weak in those plots that extend that far. Two sites, however, extend to the 1650s. Three sites (DVC, SWP, and WCP) have the most outbreaks with 5, 5, and 4 respectively. The suppression after 2000 may be related to damage from mountain pine beetle rather than pandora moth.

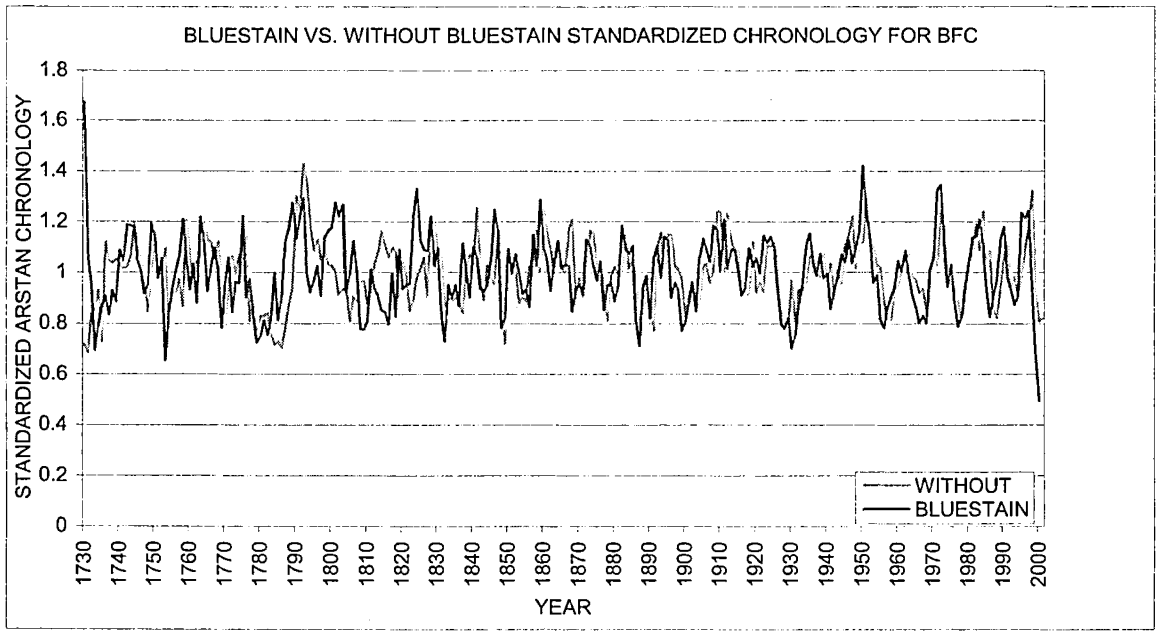

Figure 2: Blue stain and non blue stained cores for BFC site.

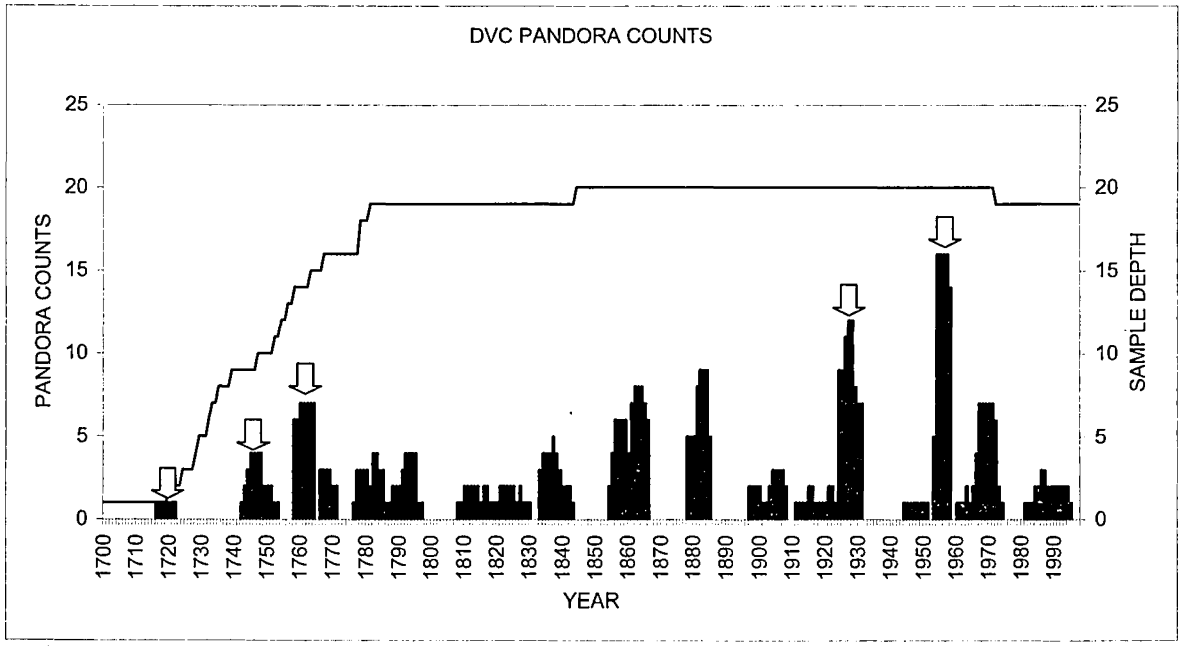

Figure 3: Pandora outbreaks and sample depth for DVC site. Arrows indicate an outbreak.

DISCUSSION

The relatively short length of our chronologies restricts the possible length of pandora moth reconstructions prior to Forest Service records. We have evidence for outbreak suppressions in 1683, 1719, 1757, 1833, 1865, 1882, 1894, 1914, 1928, 1939, 1956, 1965, 1985, and the 2000s. The early part of our record (prior to 1800) has low sample depth, but since our conservative OUTBREAK parameters associated with pandora moth can be documented in lodgepole pine, we should be able to reconstruct past outbreaks even with low sample depth in the early part of the record. These sites demonstrate the normal lag in the initiation of the pandora moth signature (see Speer *et al.* 2001) as the outbreak was active in the 1930s but most trees start to record the event in 1939.

The pandora moth signature is much lighter in lodgepole pine than previously documented in ponderosa pine (Speer *et al.* 2001). Latewood is still thinner than in a normal ring and the rings are smaller than usual, but the effect is not as severe as in ponderosa pine. That combined with the restricted length of the lodgepole pine chronologies (because of its shorter life span), make future pandora moth reconstructions in lodgepole pine more difficult to complete.

Obvious decline in growth starts in 2002 for the mountain pine beetle effected trees. This is around the documented time of the increase in mountain pine beetle populations in the Arapaho National Forest. Severe decline in growth prior to the appearance of mountain pine beetles was not documented in this work, but more analysis needs to be conducted.

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